Micro-Scale, All Solid-State Li Batteries

W. C. West, J. F. Whitacre, B. V. Ratnakumar, V. White, and S. Surampudi

Electrochemical Technologies Group/Micro Device Laboratory/Center for Integrated Space Microelectronics

Jet Propulsion Laboratory
California Institute of Technology
Pasadena CA 91109

The miniaturization and integration of power sources with the devices to be powered will enable the concept of distributed sensing for a host of commercial, aerospace, and military applications. By providing point-of-use power, significant reductions in the mass associated with wiring and packaging can be obtained. Similar advantages can be gained by co-locating micro-scale batteries and integrated circuits on the same chip. For example, conventional bandgap voltage reference circuits can be quite large, and are candidates for replacement with micro-scale batteries. Analog sensors, which require careful isolation from digital noise for optimal performance, may also benefit from an on-chip micro-scale battery power.

Highly miniaturized systems such as distributed micro-sensors may experience extreme conditions such as elevated or reduced temperature, shock and vibration. Thus, the batteries providing power must be highly robust. In the case of space applications, the requirements are particularly severe; an all solid-state materials system would be very desirable. Although micro-scale, liquid electrolyte based batteries have been reported by others,[1] to our knowledge no all solid-state micro-scale battery has been documented. This paper will discuss the recent development of a fully solid-state micro-scale battery. Li batteries with active area footprints on the scale of (50 μm)^2 have been successfully fabricated and cycled.

The micro-scale battery materials system is based on Oak Ridge National Laboratories (ORNL) thin film "Li-free" design,[2] consisting of a Ti/Pt cathode current collector, $LiCoO_2$ cathode, Lipon electrolyte, and Ni blocking anode. All cell components are deposited via RF magnetron sputtering on low stress Si_3N_4 coated Si wafers. Unlike physically masked thin film batteries, the cell features are defined using microelectronic fabrication techniques such as photolithography, wet etching, lift-off, and ion milling. Approximately 20,000 cells are fabricated on a single 4" Si wafer in approximately six hours of processing time, and are readily fabricated in parallel or series arrangement, as shown in Figure 1.

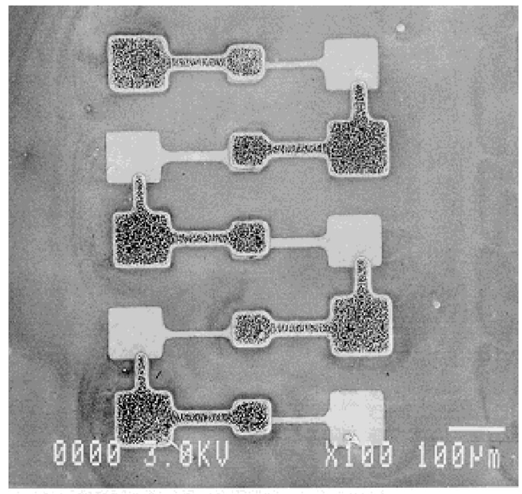

Fig. 1 Micro-scale, five cell battery with cell active area of (50 μm)^2.

The Ni blocking anode serves as a substrate for Li plating during charge. Typical discharge curves are shown in Figure 2. A dramatic improvement in cell performance is obtained when the samples are annealed at moderate temperatures of 300°C compared with cells fabricated without an annealing step, as predicted by previous thin film battery studies.[3] Further improvements in performance are anticipated with the incorporation of suitable cell encapsulation and optimization of fabrication processes.

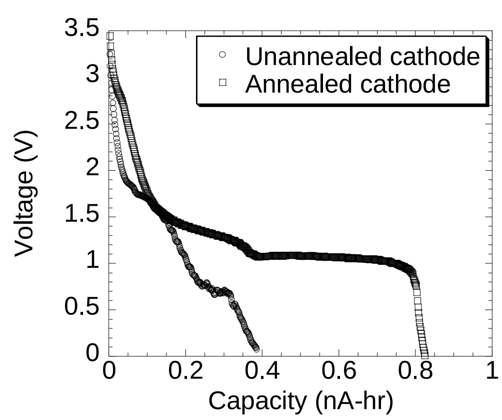

Fig. 2. Discharge curves at 10 μA/cm^2 for single (100 μm)^2 cells, as a function of cathode anneal.

Acknowledgments

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References

[1]R. M. LaFollette, J. N. Harb, and R. Humble, *Proc. of IEEE 16th Annual Battery Conf., Long Beach, CA*, 349 (2001), and references therin.
[2]B. J. Neudecker, N. J. Dudney, and J. B. Bates, *J. Electrochem. Soc.*, **147**, 517 (2000).
[3]J.F. Whitacre, W.C. West, E. Brandon, and B.V. Ratnakumar, (submitted) 2001.